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Foreword

Task 3.3 establishes methodologies to find best-practice network configurations in the domain of Reverse Logistics. Reverse Logistics encompasses all operations related to the reuse of product and material, the process of moving goods from their final destination for the purpose of added value or proper disposal. In this instance the movement of product from established collection points to further treatment plants is the segment of the network in scope.

Supply chain and logistics as an entity is operated at a macro level, with organisations not reviewing the wider benefits of collaboration and the benefits achieved with same. Road transport across Europe moves approximately 72% of goods utilised (outbound and return), with 67% of this figure being a National movement. Within this figure, 20% of trans-national vehicles and 25% of National operations respectively operate empty. Lastly, there are circa 600 thousand logistics operations across Europe, with circa 92% being an SME all contributing significant GDP to the wider European Community. Therefore, it is important to understand the opportunities that lay within the wider connected logistics networks and how these can be leveraged to improve empty running and support the important initiatives around circular economies.

The exploitation of the aforementioned spare capacity throughout these journeys via consolidation of transportation loads and pre-sorting of material streams is achieved via a provided tool developed within Java. This general-case solution is able to conduct comparisons within a user-provided configuration between current functionality, regional consolidation methodologies, and national-level consolidation methodologies. These consolidation methodologies are represented via consolidation centres at each regional/national level and the efficiencies of each approach evaluated to determine which of the three result in best-practice in regard to network efficiency. To ensure wide usability and continued benefit of the tool, the general-case approach was devised to allow individual stakeholders to provide information across a self-defined area of interest and run said analyses over the same. A User Guide is provided around usage of the tool and how to configure it for each users' particular requirements and available information. Tool instruction expects some measure of technical experience in understanding expected input formatting.

Conclusions can be used in a three-step process:

- Firstly, used to determine business models of reverse logistics for circularity will be drawn from the efficiencies output provided from the modelling exercise. The calculation procedure of this has been outlined within the design documentation. Resultant values within this file over this data set are an estimation of "Empty Kilometres" driven both before and after consolidation. The magnitude of values vary widely due to several factors: Firstly, the measurements used to determine capacity, this is a by-weight value rather than considering volume. Without considering density a vehicle may be full but be travelling at a lower weight. Furthermore, it assumes that all vehicles in the network share the same maximum capacity. The value of maximum capacity in this case was derived from the vehicle carrying the highest weight.

Secondly, this efficiency measure taken from the outputs of the modelling exercise indicates whether there exists a benefit in construction of the consolidation centre. There are a multitude of reasons for which "no" may in fact be the correct answer. Primarily, where a collection point exists towards the edge of a, in this case, Province and thus causes the Consolidation Point to drift towards it, causing all other collection points to have to now travel further. In these cases, it is recommended to repeat the

exercise over that single province after pruning from it these outliers. These outliers were kept in the dataset as they still formed part of the Provinces functionality.

- Lastly, outputs of data once processed through the modelling exercise can be uploaded to the Horizon 2020 funded AEOLIX platform, to give connected visibility of logistics providers, embrace underutilised multi-modal capacity and benefit the plethora of SMEs within the logistics sector.

In closing, from the results of the case study below, it is observed that, given the provided data, there is cause to consolidate materials in a number of provinces, thus improving efficiencies in logistics. When a review of the multiple regional consolidation centre approach is deployed, a decrease of 2.3Mg/Co2 is achieved, bringing about a €1.2M reduction in social costs and an overall logistics cost saving of €300k annualised. However, the model reviewed a singular cross dock consolidation site (opposed to multiple), deploying recognised economies of scale benefits in logistics. This approach reduced Co2 emissions by 19.1M/g/Co2 lowering social costs by €2.5M and has an overall logistics saving of €2.4M while contributing to moving more product into the circular model and away from scrap dealers (better processing). There are further benefits to be attained. Additionally, if multi-modal networks are considered as part of the wider circularity reverse logistics models, far reaching commercial and social objectives can be attained, such as modal shift to inland water would net an additional €1.8M in social costs.

Therefore, a circular economy reverse logistics business model can not only meet the needs of reducing plastic waste, but in doing so can form business models that are commercially viable and supported by existing holistic supply chain visibility tools [AEOLIX], as discussed later in section 6.3.

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1. Introduction

Task 3.3 is centred around the current landscape of Reverse Logistics and devising a methodology through which inefficiencies within said landscape can be addressed. Reverse Logistics is concerned with any process arising at the end-of-life of a product, and the way(s) in which said product is handled. The focus of this task is identification and rectification thereof these inefficiencies within the product end-of-life handling process.

Supply chain and logistics as an entity is operated at a macro level, with organisations not reviewing the wider benefits of collaboration and the benefits achieved with same. Road transport across Europe moves approximately 72% of goods utilised (outbound and return), with 67% of this figure being a National movement. Within this figure, 20% of trans-national vehicles and 25% of National operations respectively operate empty. Lastly, there are circa 600 thousand logistics operations across Europe, with circa 92% being an SME all contributing significant GDP to the wider European Community. Therefore, it is important to understand the opportunities that lay within the wider connected logistics networks and how these can be leveraged to improve empty running and support the important initiatives around circular economies.

With a circular economy perspective, these inefficiencies identified sit within the networks established in transporting product and goods from a collection point to their final treatment location. These treatment locations vary in size and function depending on the products handled there. Collection points typically amass several 'streams' of product with various final-locations for each. As treatment locations often receive product from several collection points, task 3.3 sets about establishing a more efficient methodology for this process. Inefficiencies in this regard are defined as the transportation overhead from collection point(s) to treatment plant(s).

The first step to take is determining potential alternate approaches to the current single-lane approach to transit, as well as the overarching goals any solution must meet. A programmatic approach to any solution has been deemed most appropriate due to the wider scope it affords, meaning various stakeholders will be able to derive benefit from it. Once a suitable approach to the problem has been decided, the program implementation can be designed to result in a single-purpose, yet powerful tool in determining network configuration alterations to enable a more holistic logistical landscape, ultimately saving on overhead cost associated with transporting said goods.

In summary, PolyCE 3.3 has sought to address the current landscape of potential circularity models within the holistic supply chain context. In doing so, it took robust data from known entities, which was robust and validated to build a picture of opportunity. This data, through a programmatic approach built a review of a system that reviewed National versus Regional consolidation centres. This then gave a number of vehicular movements, which can be reviewed against the amount of empty running in Europe, thus creating reverse logistics business models based on existing spare capacity. Lastly, the opportunity exists to engage with SMEs in logistics through the European funded AEOLIX project (www.aeolix.eu) to offer connected supply

chain communication to facilitate the 'real-time' delivery of logistics efficiencies in circular economy reverse logistics.

1.1 Problem Background

The solution will take the form of a programmatic tool of a general-case problem with flexible input handling such that as wide a range of stakeholders can make use of the resultant tool as possible. The outputs of same were evaluated by a series of logistics and supply chain experts to build a robust output that defines a 'state of the art' approach to circularity with logistics. These proposed outputs and solutions can then be uploaded to AEOLIX for wider embracement by European logistics operators in building robust reverse logistics networks.

1.2 Problem Definition

The problem identified is that of removing inefficiencies in transport operations of end-of-life goods from collection points to treatment plants. Inefficiencies arise where the system relies on single-lane transportation where vehicle load factors may not be optimal. It is infeasible to assume that collection points will be able to store goods indefinitely until an optimal load factor can be achieved, furthermore, it is unlikely that treatment plants operations can be halted and altered to accommodate less regular, but full, vehicle loads. Therefore, the problem to solve is finding alternate transportation methods of transporting goods from collection to treatment. This solution must allow current delivery schedules can be maintained, as well as result in more optimal load factors of transported goods.

1.3 Problem Solution

The proposed solution is the inclusion of a new node within the transportation network. Instead of just Collection Points and Treatment Plants, include Consolidation Centres in addition to these. Consolidation centres function as an intermediary destination where goods of identical streams and destination can be stockpiled until such a point that transportation to the relevant destination can be performed at a more optimal load-factor.

The key problem to solve here is determining the optimal location of any consolidation centre. To provide greater functionality, and for more powerful analyses, both regional and national consolidation centres will be considered. The methodology for determining where to locate consolidation centres will be based upon determining the centre points in cluster analysis, or, finding centroids.

Of course, solving logistics problems in theory is great for strategic planning. However, what is really needed is a call for action in bringing these solutions to life. In this task we are suggesting stakeholders engage with the AEOLIX platform through UON [University of Northampton] to utilise real data post solution finding to source alternative multi-modal transports across Europe. Therefore, solutions take a strategic (planning) approach and then permit tactical/operational solutions to be taken up by willing participants.

1.4 Solution Evaluation

Any solution will be evaluated against a series of real-world ‘as-is’ data sets in the instance where no information on throughput is provided, then simulated data can be provided to determine the point at which regional/national consolidation centres become a more efficient alternative.

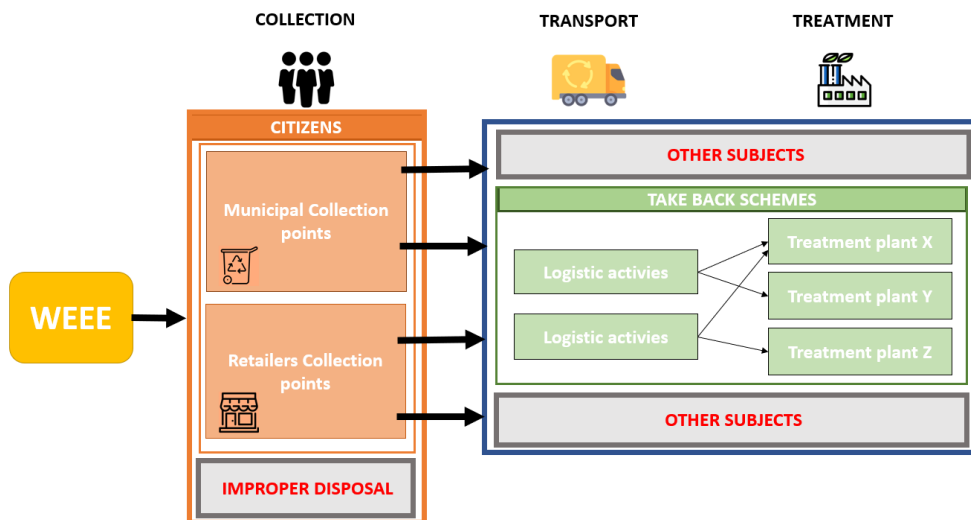
2. Case & Methodology

2.1 Cases Considered

The primary case considered is over a dataset as provided by ECODOM. ECODOM’s dataset numerically describes the current Italian WEEE value chain (an accurate description of WEEE value chain is provided in PolyCE deliverable 3.1 - *Quantification of material flow along the entire chain*). Along the WEEE valued chain there are several actors involved in the (in)correct waste management.

When the EEE becomes WEEE, Original Equipment Manufacturer (OEMs) must adhere to the WEEE Directive (2012/19/EU).¹ The directive, based on extended producer responsibility (EPR), states that manufacturers and importers of EEE are responsible for the end of life of their products. OEMs may either setup their own system, or assign a third party to execute these regulations. In practice, OEMs often work collectively to exert their responsibility by setting up Producer Responsibility Organisations (PROs). PROs (or **take back schemes**) help collectives of manufacturers fulfil their legal requirements with respect to waste management.

Take back schemes are one of the main nodes of the WEEE reverse logistic activities; there other relevant nodes in the WEEE reverse logistic chain as



reported in the graph below.

¹ European Commission, DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast), 2012

More in detail, WEEE reverse logistic main activities are:

- collection activities:
consumer, who decides to discard its EEE equipment, has the possibility to choose between different options according to the national regulation and city's waste management system. For instance, in Italian consumers can dispose WEEE through municipal collection points and retailers collection points.

However, citizens too often simply continue to accumulate their WEEE in households or **improperly dispose** it in municipal undifferentiated waste (the disposed of e-waste is then treated with the regular mixed-waste from households, this is especially the case for small WEEE)¹. If consumers directly dispose of e-waste through normal dustbins with other types of household waste, the disposed of e-waste is then treated with the regular mixed-waste from households;

- transport and treatment activities:
Take back schemes are in charge of the transport and treatment activities. Take back schemes are in charge of WEEE transport and WEEE treatment activities. Take back schemes put in place logistic activities through authorized transport operators that use trucks for tipping containers (if the served collection point is managed by a container) or trucks with tail lift (if the served collection point is managed by manual picking). Transport operators deliver then collected WEEE to authorized WEEE pre-treatment plants, where treatment operations are performed in accordance with WEEE treatment standards (e.g. WEEELabex²).

However, aiming to provide a complete description of the EEE/WEEE value chain, it cannot be denied that there are **other actors** operating in WEEE management without respecting the minimum treatment quality standards or **illegally**. For example, a considerable amount of WEEE is illegally exported out of EU or irregularly treated. A study realized by the WEEE Forum, a not-for-profit international association of 31 WEEE PROs, informed that in Europe just 35% (3.3 million tonnes of 9.5 million tonnes) of electronics and electrical equipment discarded by companies and consumers in 2012 ended up in official collection and recycling systems³. When WEEE are disposed outside the official take-back system, it is then difficult to trace them (e.g. not official and standardized statistic available). It is then possible that WEEE are dumped, traded, or recycled with low recycling standards.

From the consideration above, it is evident that there is a considerable gap between the WEEE generated and the WEEE collected (corresponding to

¹ L. Darby, L. Obara, Household recycling behavior and attitudes towards the disposal of small electrical and electronic equipment, *Journal of resources conservation & recycling* 44, pp. 17–35, 2005

² WeeeLabex Standards, available at <http://www.weeelabex.org/standards/>

³ Huisman, J. et al., *Countering WEEE Illegal Trade (CWIT) Summary Report, Market Assessment, Legal Analysis, Crime Analysis and Recommendations Roadmap*, Lyon, France, 2015

the WEEE collected through official channel, thus traceable and clearly measurable). In 2016, the collection rates (the percentage of the WEEE collected over the total WEEE generated) were 38% for Europe (28% for Italy). The remaining 62% of WEEE is exported, recycled under non-compliant conditions in Europe, scavenged for valuable parts or simply thrown in waste bins by citizens¹.

Therefore, this deliverable will study two scenarios:

1. As is scenario:

the actual scenario has been modelled using realistic and accountable data, regarding WEEE management activity performed by ECODOM during the first three months of 2017 (data refers to logistic and treatment activities carried out in three different Italian regions and bring to more than 8,300 tons of delivered WEEE and more than 235,000 km travelled).

2. Assumed scenario:

this second scenario has been elaborated assuming that all the WEEE generated would be collected. Namely, it is assumed that citizens dispose the entire amount of WEEE generated through proper channels (e.g. municipal and retailers collection points) and that WEEE collected are then transported and treated entirely by take back schemes.

This additional scenario has been developed only for the Milan Province for the Cooling and Freezing (C&F) and the Large Household Appliance (LHA) waste flows. The corresponding dataset has been elaborated taking into account:

- the estimation of the amount of WEEE (kg/inhabitant) generated in Italy per WEEE stream performed by the according to the study commissioned by ECODOM to UNU in 2012 to better understand Italian consumer disposal behaviour for WEEE. The estimation was based on a combination of detailed reconstruction of the historical POM data for different types of EEE, the quantification of the accumulated EEE stocks in households, and the creation of life-time profiles for various EEE. From the mentioned study, it results that Italians on average generate yearly 2.4 kg/hab of C&F and 5.18 kg/hab of LHA;
- the population of the municipalities within the Milan Province;
- the current average load of the trucks actually performing the collection activity in the municipalities within the Milan Province.

¹ K. Baldè, V. Forti, R. Kuehr and P. Stegmann, The Global E-waste Monitor, United Nations University (UNU), International Telecommunication Union (ITU), International Solid Waste Association (ISWA), 2018.

The first two pieces of information listed above allowed to estimate the amount of WEEE that would be potentially collected improving the collection performance; the third information has been used to calculate the number of transports potentially needed to deliver the collected WEEE to the treatment plant.

The estimated data set brings to more than 1,400 tons delivered and more than 75,000 km travelled for C&F WEEE stream (the current value are more than 600 tons delivered and more than 29,000 km travelled); while for LHA WEEE stream, the performed estimation brings to more than 3,000 tons delivered and more than 32,000 km travelled (the current value are more than 1,600 tons delivered and more than 13,000 km travelled).

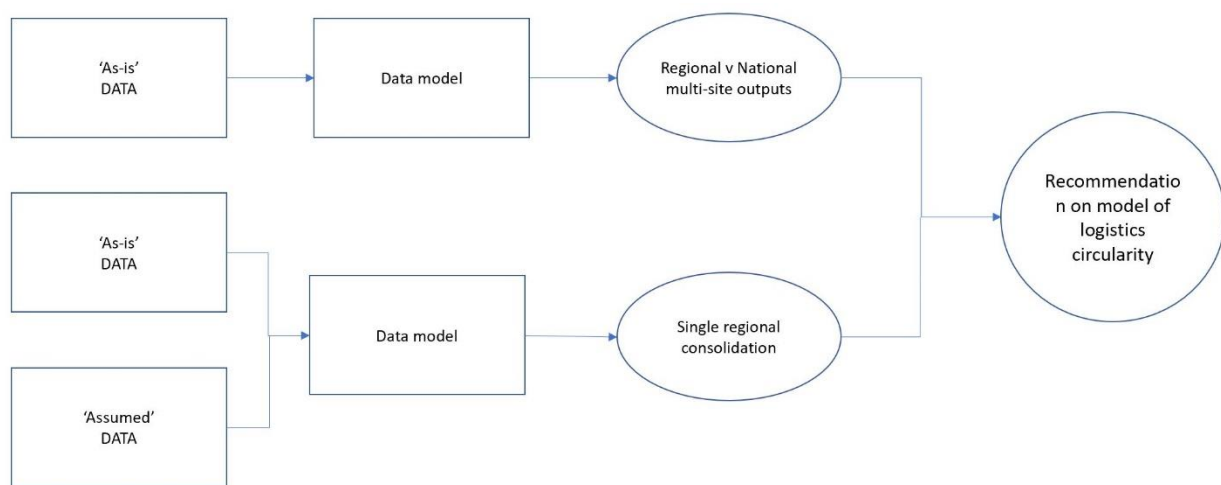


Fig.1 Method flow

Utilising the aforementioned data sets, the logistics research methodology followed two flows (Fig.1). The outcome of which was to deliver a recommendation on a model of reverse circularity with logistics value chain members/actors.

2.2 Methodological data analysis flow

The datasets described above are the input information used by the developed optimization tool that will identify the optimal location for a Consolidation Centre. The introduction of a Consolidation Centre will improve the WEEE reverse logistic performance reducing the overall travelled km.

The dataset as provided firstly required pre-processing and Geocoding. The table below outlines the provided columns, and which were removed, reordered, or processed further.

Column Title	Processing Performed
WEEE Flow	Removed as unnecessary for requested analyses.

Date of the Transport	Removed as unnecessary for operation.
ZIP CODE of the Collection Point	Kept as utilised in Geocoding to ascertain locations of any origin.
Province of the Collection Point	Kept. Used as the 'Region' field for operation. Further processing was required in translating region names to a numerical value. This column was copied into a secondary sheet and an ID 1 – 32 assigned to each. A VLOOKUP was performed in Excel to then assign a Region ID to each of these locations.
Location of the Treatment Plant	Removed as unnecessary for operation.
ZIP CODE of the Treatment Plant	Kept as utilised in Geocoding to ascertain locations of any destinations.
Name of the Treatment Plant	Removed as unnecessary for operation.
Delivered Quantities (KG)	Kept. Renamed to 'Carried Capacity'
Distance Travelled (KM)	Kept. Renamed to 'Distance'
Transport Operation Location	Removed as unnecessary for operation.
Transport Operator Location ZIP CODE	Removed as unnecessary for operation.
Transport Operator Name	Removed as unnecessary for operation.
Transport Operator Subcontractor	Removed as unnecessary for operation.
Transport Operated by the Treatment Plant	Removed as unnecessary for operation.
Region	Removed as the 'Regions' of interest were the provide Provinces

Following this pre-processing stage the columns were arranged into the following order, as per the required configuration for successful execution of the tool.

Column	Column Title
A	Region
B	Collection Point Latitude
C	Collection Point Longitude
D	Treatment Plant Latitude
E	Treatment Plant Longitude
F	Carried Capacity
G	Maximum Capacity
H	Distance Travelled

There is one caveat to this approach however, when calculating efficiencies, the maximum capacity of vehicles is required to ascertain a measure of

journey load factor. Additionally, due to variable densities of product, a direct Kilogram measurement will yield variation in results as a more accurate measure would be cubic space occupied. The tool has been generalised to account for both these scenarios should the information be provided. The output of the tool in this instance was a number of Regional Centre locations, one for each Region. Some regions yielded zero output in this instance due to complications with Geocoding ZIP Codes, these are marked with NaN (Not a Number). The proposed Regional Centres are listed in the following section.

3 Results

3.1 Case study 1 - Regional Centre Output

The initial set of ‘as-is’ data for the three regions were calculated through the tool to determine as a first step whether any efficiencies can be made. It is a well-documented phenomena that often logistics operations will by their very nature of being low margin, move to create efficiencies within their own operation. This process often leads to negative results with logistics and operations research.

This was identified with the current ‘as-is’ dataset (Table.1), with only four regions being able to be consolidated on the approach of consolidation centres based on volume and distance.

Region	KG	Improvement
1	500,770	Yes
2	114,100	Yes
3	404,800	Yes
4	885,770	No
5	2,549,920	No
6	109,530	No
7	31,600	No
8	426,164	No
9	232,815	No
10	221,460	No
11	335,750	No

12	114,970	Yes
13	465,360	No
14	67,240	No
15	99,850	No
16	764,850	No
17	150,040	No
18	241,465	No
19	112,670	Yes
20	72,660	No
21	5,260	No
22	18,160	Yes
23	93,930	Yes
24	3,520	Yes
25	63,500	No
26	5,180	Yes
27	60,120	Yes
28	1,940	Yes
29	160,520	No
30	12,720	Yes
31	2,620	No
32	44,740	No

Table.1 Test case location site

The outputs were modelled visually within QGIS to give the expert evaluation team an opportunity to sense check the outputs, with the proposed locations of Regional Centres in Red/Pink (Fig.2).

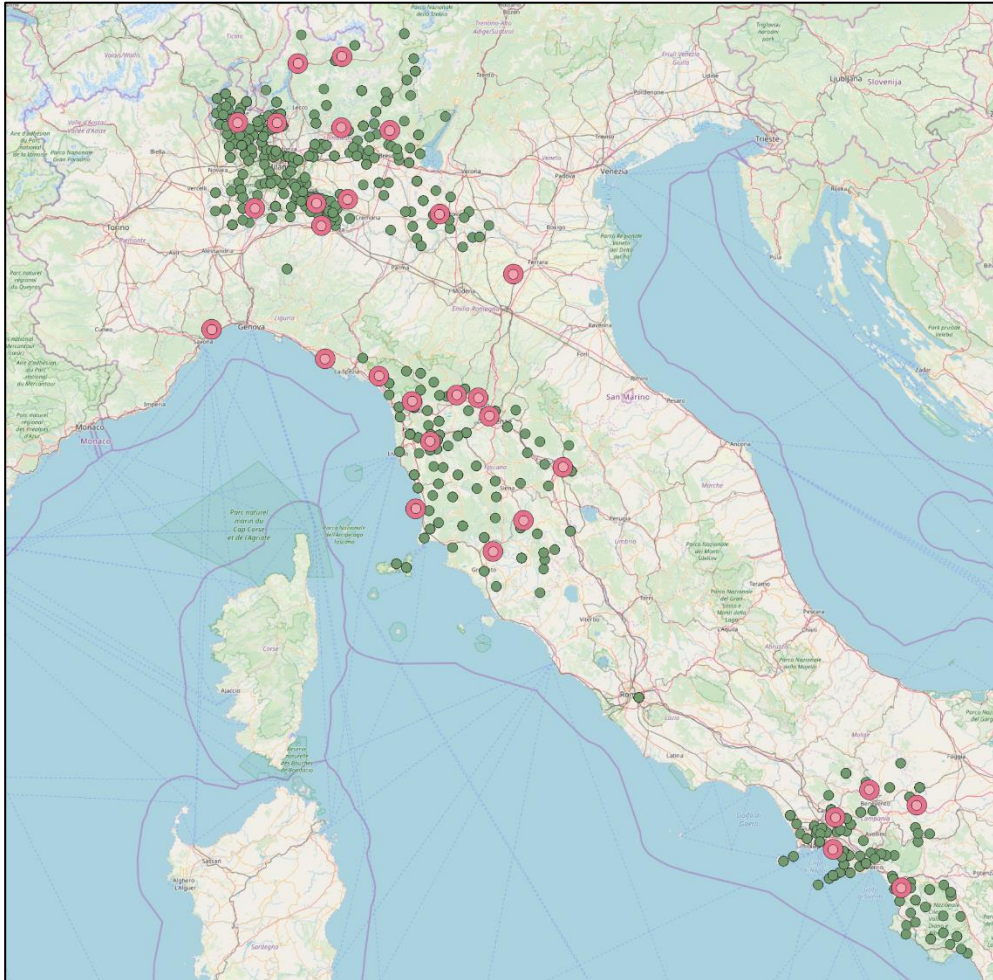


Fig.2 Collection and consolidation sites

The model was run at both regional and national level, in order to build an understanding of circular economy business models and the benefits of National Consolidation Centre (NCC) versus Regional Consolidation Centre (RCC).

	KM (Pre)	KM (Post)	Difference (KM)	Gm Co2 reduced	Social cost (per QTR)
Regional	235,901	198,294	37,607	2,331,634	€ 303,180
National	235,901	225,142	10,759	667,058	€ 86,170

Table.2 Outputs from regional logistics efficiency review – National vs Regional (Quarterly)

It was noted that there were efficiencies in stem mileage in both models (Table.2), however, in pure road logistics terms; the regional centres are more efficient from tonne kilometres and Co2 emissions reductions. It is worth noting this study did not take into account the reduction in plant operating efficiencies which in this example reduce 23 plants to 1. That said,

it would be suggested that consolidation centres form part of existing logistics infrastructure to mitigate this factor. Lastly, this model operated over 'a day in the life' demonstrating a quarter year effect and would need to be extrapolated up to annual in order to reflect the full year effect (Table.5).

	Per annum	Per month
Fuel	€ 110,090	€ 9,174
Finance	€ 57,501	€ 4,792
Depreciation	€ 7,500	€ 625
Fixed cost	€ 92,788	€ 7,732
Driver	€ 98,618	€ 8,218
Tyres	€ 17,252	€ 1,438
Maintenance	€ 13,988	€ 1,166
Service	€ 8,655	€ 721
	€ 406,392	€ 33,866

Based on
 Fuel
 Prices inclusive of road tolls, insurance, registration and social insurance
www.freightmetrics.au

Table.3 Vehicle cost reductions associated with regional model

The base model eradication of stem mileage would reduce €406k (annualised) of fully costed operational budget from the existing operation based on validated calculation tools (Table.3). There would be on-cost of £1.3M per annum for the consolidation centres (Table 4). Therefore, the overall on-cost of €1.3M logistics infrastructure, €406k operational saving alongside €1.21M (Table 5) of social impact savings, delivers a NET benefit to the network of €318k per annum.

	Count	P/A cost	Total P/A cost
Consolidation ctr	9.00	€145,000	€1,305,000

Table.4 Consolidation centres

3.1.1 Reverse logistics in multi-modal context

On review of the data from the desk top exercise of circular reverse consolidation National versus Regional (Table.2), critical metrics are observed, such as sites that can be made efficient in this 'use case' can

decrease empty running by 37,607 KM, estimate reduce 2.3 Million gm/Co2 and proffer opportunities additional full truck loads to logistics SMEs across Europe (estimated €136,801 increased revenues from fuel saving).

	Truck Efficiency (Co2 gmt/km)	Rail Efficiency (Co2 gmt/km)	Barge Efficiency (Co2 gmt/km)
Co2 gm/t/km	9,326,536.00	12,590,823.60	13,989,804.00
Co2 tonnes	9,327	12,591	13,990
Social saving (\$)	€ 1,212,449.68	€ 1,636,807.07	€ 1,818,674.52
Logistics saving (€)	€ 406,392.00	€ 406,392.00	€ 406,392.00
Total	€ 1,618,841.68	€ 2,043,199.07	€ 2,225,066.52

Table.5 Estimated commercial savings – Regional Multi modal

In addition, by leveraging the AEOLIX integration (www.aeolix.eu) as discussed in section 5, the circular logistics models can make avail of ‘real-time’ data on empty vehicles across Europe. Furthermore, this model of real-time information data exchange permits operators the potential for modal shift to be achieved within the circular economy business model. A good example of this can be seen with modal shift to rail or barge, which in this example, if a target of 50% modal shift was achieved a shift to rail would NET an estimated additional 1.6 Million tonnes per KM Co2 reduction, with waterway (barge) a potential 1.7 Million tonnes per KM Co2 (Table 5).

Furthermore, based upon the research of Howard and Sylvan [2], the social cost per tonne of Co2 is €130. Therefore, the proposed reverse logistics circularity model would have a cost saving to society of €1.21M in the regional desk top model proposed, in road logistics alone.

In summary, the theoretical circular logistics business model has a cost of €1.3M through consolidation centre operation, but an operational and social saving of €1.61M, netting €301k annualised.

3.2 Case study 2 - Milan consolidation case study

The second case study model reviewed the option of a regional consolidation centre in Milan utilising two streams of waste (C&F and LHA). Instead of modelling numerous consolidation centres, and after reviewing the data, it was the view of the logistics experts that a further model should be explored. This model considered a total tonnage of 18M/t per annum, across 1,686 different collection sites, which operates currently by filling vehicles and once complete a 200km round trip to one of the regional treatment plants.

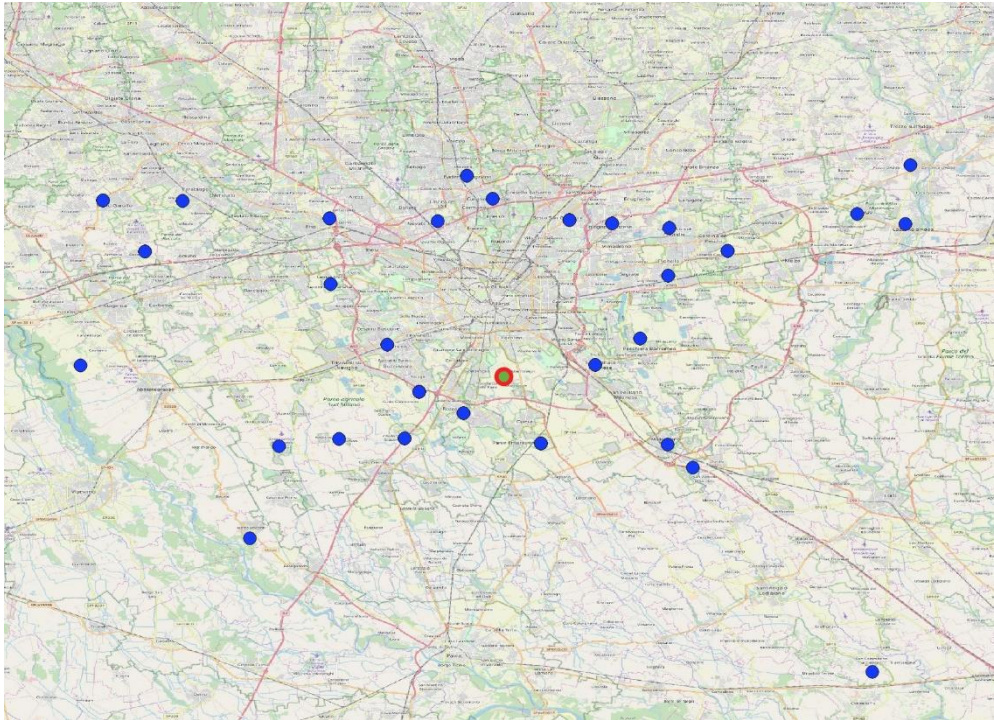


Fig.3 C&F collection sites and modelled consolidation centre

In undertaking the analysis, this model looked to eradicate as much as possible the stem mileage of vehicles operating between collection points and the treatment facilities, as this was deemed as the most wasteful leg in the overall operation.

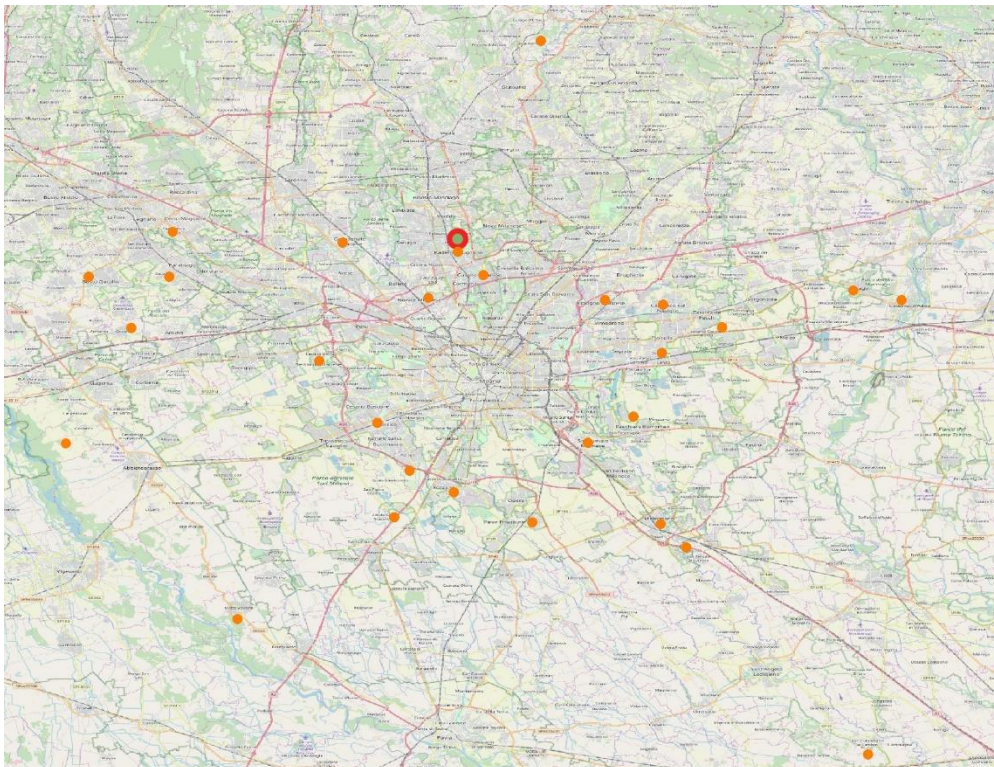


Fig.4 LHA modelled collection sites and centralised consolidation centre

The figures 3 through 5 depict the visual modelling exercise of scenario 2, the Milan centric operation with one cross dock consolidation site. Fig.3 depicts only C&F product, Fig.4 the HLA product and Fig.5 the consolidated view of both streams.

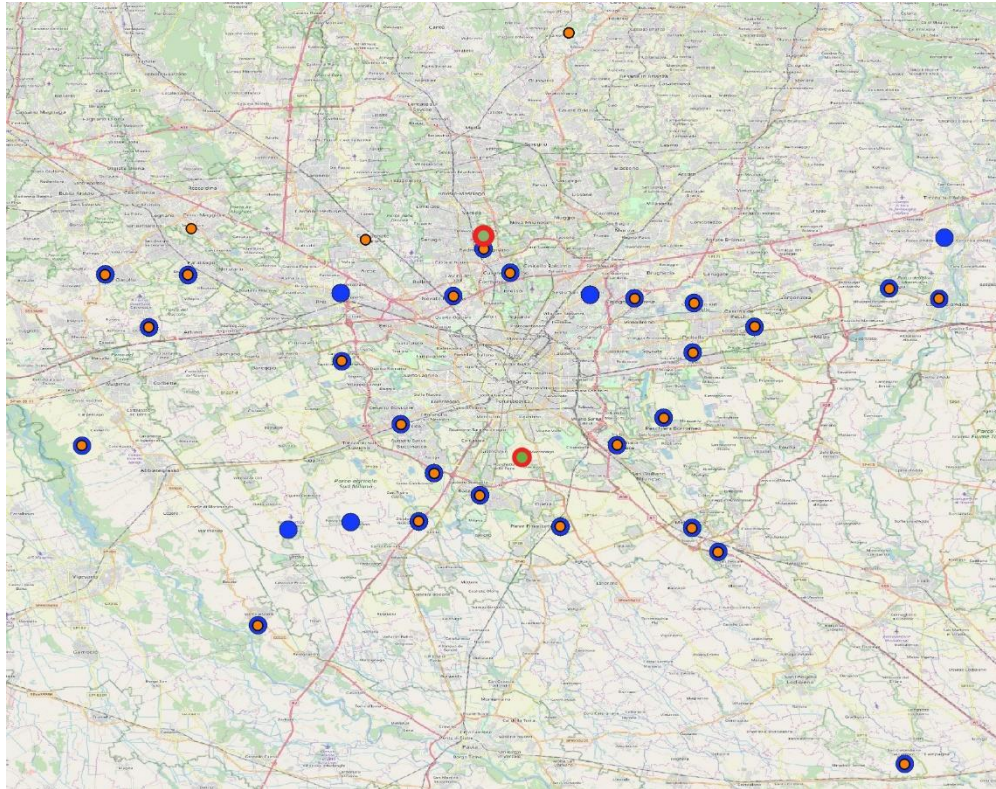


Fig.5 Both streams mapped

Next steps in the modelling process saw the team undertaken a detailed cost analysis of the now versus future model (Table.6).

Stream	Collection point	Delivered quantities kg (per qtr)	Distance travelled km (per qtr)	New distance travelled (per qtr)	Difference (per qtr)
C&F	735	1,469,778	75,175	4,410	70,765
LHA	951	3,042,181	32,331	6,182	26,150
	1,686	4,511,959	107,506	10,592	96,915

Table.6 'As-is' versus proposed

This step identified a significant reduction in stem mileage across both streams (Table.6), largely as the vehicles are now concentrated on collecting product opposed to travelling 200KM round trip to treatment plants.

	Site	oads	Avg istance	Total trip time	Resou rce hours	Truc ks	Trucks now (est)	Cost now	Cost future
C&F	2	10	7.35	4	39.19	4.90	10	€ 2,916,814	€ 1,458,407
LHA	2	10	10.302	4	40.56	5.07	10	€ 3,018,645	€ 1,509,322
								€ 5,935,459	€ 2,967,729

Table.7 Streams mapped by 'First mile' delivery model with costs

The two streams were mapped against a dedicated fleet of 'first mile' collection from across Milan region. Based on vehicle capacity and usage of the 'as-is' position, C&F are operating 2,500kg (FTL) and LHA 5,000kg (FTL). Utilising recognised fleet costing tools (Freight Metrics) [3], an estimated now figure has been attained, while also building a costing matrix for dedicated 'first mile', depicting differences with same (Table.7).

	Loads p/d	Total time	Resource hours	Trucks	Load rate	Back haul cost	Dedicated fleet cost
C&F	4	3	13.4	1.7	800	€ 117,582.27	€ 853,430
LHA	5	3	15.2	1.9	800	€ 121,687.24	€ 853,430
						€ 239,270	€ 1,706,860

Table.8 Streams mapped by 'Line haul' delivery model with costs

Next steps, was to build a picture of the 'line haul' requirements for the two streams, from the proposed consolidation centres to the respective treatment plants (Table.8). Two methods were used:

- Dedicated fleet
- Back haul

Dedicated fleet has clear advantages in that vehicles will operate on behalf the consolidation centre, with full control being maintained by the circular logistics model operation. However, the draw back is all costs need to be born by the operator, and this model will have an element of empty running back to the consolidation centre, thereby partially negating the model.

A back-haul proposal, goes toward the 20% of National empty running reduction that currently resides within Europe, and proffers much greater cost saving in terms the load rates being offered.

This model does not recommend the final solution, instead places the data for discussion as differing regions and nations, will have competing or specialist demands, and consideration for logistics line haul system will be a local decision.

	Manager	Supervisor	Operative	Site	Insurance	Total
Cross dock	€ 65,000	€ 55,000	€ 102,500	€ 75,000	€ 25,000	€ 322,500

Table.9 Cross dock (consolidation centre) costs

A base cost for consolidation centre has been created (Table.9). Despite the model proffering two consolidation centres, one for C&F and another for LHA. It is a recommendation of the study that one Milan site be utilised to the West of the city, giving the benefits of consolidated economies of scale.

	Site	Line haul	First mile	Total	NET
Dedicated	€ 322,500	€ 1,706,860	€ 2,967,729	€ 4,997,089	€ 938,369
Back haul	€ 322,500	€ 239,270	€ 2,967,729	€ 3,529,499	€ 2,405,960

Table.10 various models compared against the now position

The two models were presented (Table.10) to identify a regional circular logistics model through a cross docked consolidation centre approach. Both models came out with a surplus against the current model, and it is worth noting this is pure logistics operational cost and does not include the social impact benefits, which while this model would reduce 19.1M G/Co2 equates to an additional social cost reduction of €2.5M. Therefore, a dedicated fleet option would NET social and operational savings of €3.43M p/a and a back-haul operation €4.9M annualised.

3.3 Conclusions

Conclusions will be drawn from the efficiencies output of both case study models as provided. The calculation procedure of this has been outlined within the design documentation contained within the appendix of this document. Resultant values within this file over this data set are an estimation of “Empty Kilometres” driven both before and after consolidation. The magnitude of values vary widely due to several factors: Firstly, the measurements used to determine capacity, this is a by-weight value rather than considering volume. Without considering density a vehicle may be full but be travelling at a lower weight. Furthermore, it assumes that all vehicles in the network share the same maximum capacity. The value of maximum capacity in this case was derived from the vehicle carrying the highest weight.

This efficiency measure then indicates whether there exists a benefit in construction of the consolidation centre. There are a multitude of reasons for which “no” may in fact be the correct answer. Primarily, where a collection point exists towards the edge of a, in this case, Province and thus causes the Consolidation Point to drift towards it, causing all other collection points to have to now travel further. In these cases, it is recommended to repeat the exercise over that single province after pruning from it these outliers. These outliers were kept in the dataset as they still formed part of the Provinces functionality.

In closing, from the results above it is observed that, given the provided data, there is cause to consolidate material in Provinces 3, 12, 19, 23 and 27. When we overlay a regional Milan cross dock consolidation centre there are efficiency metrics attained of €4.9M, of which €2.5M is a social benefit through the reduction of 19.1M G/Co2 by mitigating stem mileage in vehicle line haul. Additionally, if multi-modal networks are considered as part of the wider circularity reverse logistics models, far reaching commercial and social objectives can be attained. Therefore, a circular economy business model can not only meet the needs of reducing plastic waste, but in doing so can form business models that are commercially viable and can be supported by existing holistic supply chain visibility tools, as discussed later in section 6.3.

4 Benefits, recommendations & next steps

Optimization of logistic activities for WEEE is passing through the optimization of the loads. The solution identified through the bi-modelling process is the introduction of a consolidation center that will collect WEEE from the various collection points that do not fulfil adequately the container/the truck to justify a long trip to the treatment plant, i.e. a direct line haul. This is a scenario that is endemic across Europe, predominately around the smaller nature of product being moved.

4.1 Benefits

The benefits of introducing a consolidation center has been evaluated and are summarised below.

- **to reduce km (stem mileage) and therefore reduce number of vehicles**

The use of a cross dock consolidation center located in the gravity center of collection volumes for a determined area permit less trucks kilometres per trip. This is achieved by reducing the need for vehicles to always route to a treatment centre, which in the case study supplied is 200km round trip, vehicles instead perform task and make circa 20km round trips to a cross dock consolidation centre.
- **More efficient trips**

By vehicles staying local, better use of driver operator and vehicle time can be made with collecting waste product, rather than the wasteful process of stem mileage (200km round trip to treatment centre).
- **indirect benefits**
 - **Cost for society**

Reducing stem mileage and therefore increasing cost efficiency in logistics has the added benefit of intangibles. The key intangible is the reduction of CO2 emissions from vehicles, which in the Milan single centre is estimated to be €2.5M per year.
 - **Service rate**

Due to the shorter mileages for collection vehicles (eradication of stem mileage), the overall investment, depreciation and day-day operational costs reduce, therefore, delivering cheaper services to the various stakeholders from consumer to local authority.

- **Cost for logistic activities**
The cost for logistics decreasing, will make market entry, uptake in areas not currently having WEEE circular logistics models and continual investment in the sector attractive.
- **Cost for treatment activities**
Having a consolidation centre means, smaller volumes can be pulled together to get greater economies with line haul vehicles that operate from cross dock consolidation centre to treatment plant. Instead of being stacked as the vehicle routes, current standard practice, the vehicle can be stacked in a revised manner that would permit greater volume to be transported.

4.2 Recommendations

- **Reliability check of the current logistic costs**
A current 'as-is' model of consolidation has been identified. It is recommended by the logistics experts that further work be undertaken in this area, to deconstruct the operational costs, permitting a validation of the theoretical model contained within this report. This activity will add value when it comes to gaining wider stakeholder engagement and uptake outside of the test case scenarios.
- **Better results if the quantity collected increase**
The model proposed will only work if economies of scale are evoked through the use of greater take back scheme use. The current process of permitting WEEE to scrap yards needs to cease, and flow through models as suggested here. This will not only have a social intangible benefit, hugely reduce the cost of logistics operations, but permit flows of plastic into the value chain that can be reused, thus making the wider value chain more efficient.
- **Consolidation centers are effective for areas without the full load phenomena of larger cities**
The model proposed takes an 'all inclusive' approach to logistics reverse models to support the circular economy of plastics within Europe. By adopting a cross dock consolidation approach, there is no region or country that could not adopt this and benefit from efficient logistics operations.
- **Living lab**
The study has shown how models of circularity can be achieved through greater stakeholder collaboration. It is recommended from

the expert panel that additional 'living lab' sites and partners be identified across Europe, to test in a micro environment some closed loop testing of the methodology.

5 Collaboration with wider European logistics operations (AEOLIX)

5.1 Connected visibility

As discussed, supply chain efficiency largely depends upon data and information – how it is collected, processed, stored, updated, interpreted, understood, and exploited. On an operational level, actors need actionable information, sometimes in real-time, to be able to make effective decisions. On the tactical and strategic levels, the transportation system needs increased connectivity. In previous projects and ventures, much focus has been placed on creating methods of data sharing which are both centralised and standardised. The logic behind this design approach is simple: If all actors are using data the same way (classification, semantics, format etc.), many of the challenges regarding interoperability are overcome. In reality, however, these projects are likely not to succeed, often due to individual organisations that are unwilling or unable to conform to standards that do not improve their internal efficiency, or to place data under the influence of a third party. A decentralised approach, however, has its own complexity and its own challenges. By allowing individual actors to decide how information is shared, a large number of bilateral agreements become necessary and the number of prospective interfaces to maintain increases geometrically with the number of actors in a system.

AEOLIX has developed a platform for connecting logistics information systems of different characteristics, intra- and cross-company, for immediate (real-time) exchange of information in support of logistics-related decisions. This has led to the development of architecture for a distributed open system which will exchange information among key logistics actors (commercial companies as well as relevant authorities), enabling increased use and impact of such information in the value chain. During the project which concluded June 2019, logistics related business issues have been selected as use cases to be researched at different Living Labs to validate and demonstrate the benefits of the platform.

The AEOLIX Platform support services will provide not only an additional tool through the dashboard but a set of integration tools such as APIs (Application Programming Interfaces) and SDKs (Service Development Kits) to allow the integration of existing end-user systems or services and the possibility for development of new end-user applications.

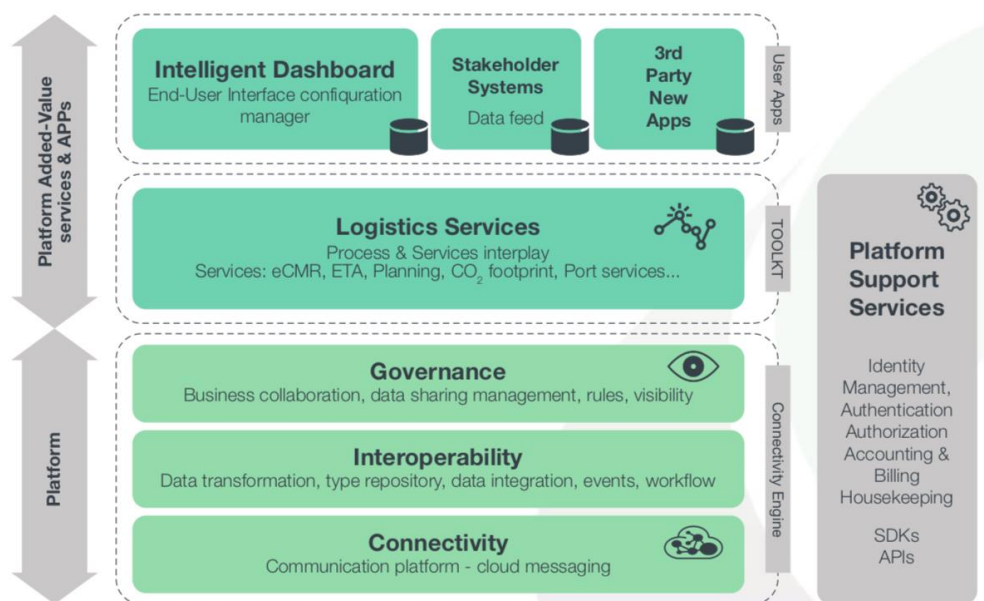
In this sense, the AEOLIX Platform provides SDKs (Service Development Kits) to develop or integrate software solutions or services for the AEOLIX Toolkit, enriching AEOLIX Platform services to help logistics stakeholders address the business needs of their processes or requesting specific cloud services. Finally, AEOLIX provides APIs to enable the connectivity of services, apps or devices running in different platforms (Java, .NET, JS...) to the AEOLIX Community Ecosystem in simplified technology integration. The AEOLIX platform provides a security framework based on a trusted model

for cloud-oriented collaborative networks and security mechanisms (identity management, authentication/authorisation mechanisms). It is aligned with EU directives and recommendations such as the e-Identification and trust services described in the Digital Agenda for Europe and aligned with the Digital Single Market.

5.2 Benefits and impacts

The AEOLIX Platform will have three releases. The platform release 0 was the launch of the project (and not the platform itself) and targeted the whole supply chain community. The subsequent platform releases of the AEOLIX project will initiate different engagement strategies for different types of stakeholders.

The AEOLIX consortium partners organised the first Platform Release 1.0 as a test fest event in September 2017 (in terms of connection) for shippers, LSPs and service providers to check the initial requirements for connecting different proprietary systems through APIs and to demonstrate the quick wins. The first Platform Release 1.0 will include the development of the main functionalities of the AEOLIX platform (connectivity engine, dashboard, and toolkit). This first platform release will allow the basic data feeds to be visible in the dashboard and also show through the toolkit and APIs how the service providers can be connected.



AEOLIX provides a comprehensive architecture for a digitally secure and regulated logistics services and information sharing platform, based on the following specific components:

The platform release 2.0 will involve the intelligence of the connectivity engine to provide added value through the toolkit services and dashboard benefits to each stakeholder. The last Platform Release 3.0 (April 2019) showcases the final product of interest to the end users. It will also be possible to demonstrate the feasibility of the AEOLIX platform as a self-service platform demo within the AEOLIX website and also to organise webinars as training /capacity building tools accompanied with appropriate

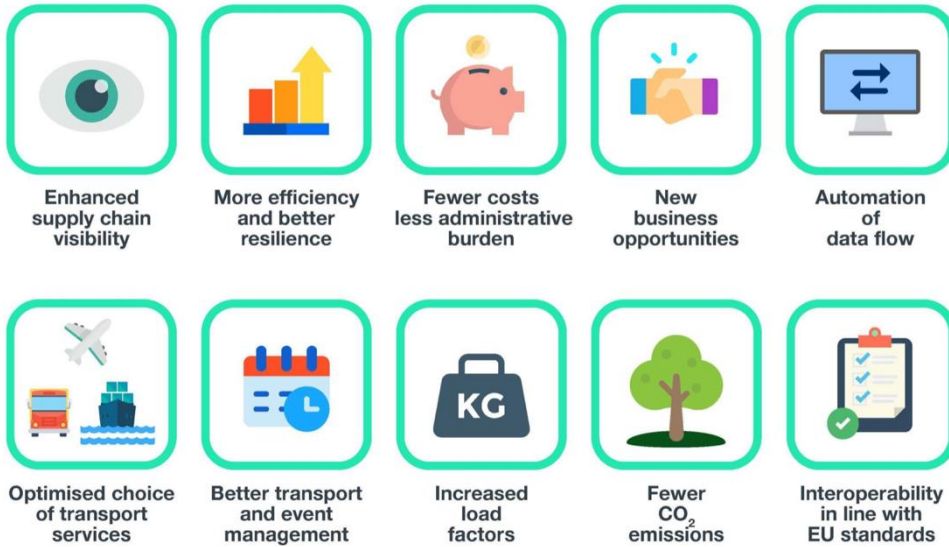
training material on how to connect and use it for specific target groups. Information days, high level meetings, conferences and other communication tools will also be used for engaging stakeholders as already planned in the first year. Each release will be validated by users and their feedback will be collected to form requirements for the next release and these will be done in the test fests events. The AEOLIX Community will play an important role in the development by giving their requirements on the Platform. Therefore, the Community building has a natural relationship with development of the AEOLIX Platform.

By examining on a component level the considered functionalities that a platform like AEOLIX could provide to enhance the different services, the different role and purpose of each component in the value chain of the services varies significantly. Components that are used more as user interfaces (e.g. Dashboard) are most relevant for improving supply chain visibility and interoperability in a distributed manner. The Service Development Kit, on the other hand, is a supporting functionality that is crucial in order to use the platform (e.g. creating Service Descriptions), but the actual impacts are realised through other means (e.g. through aggregating services by accessing those Service Descriptions through the Service Directory). The impact of AEOLIX is strongly dependent on the availability and accessibility of the services to a large number of users. Making the platform as user-friendly as possible is essential for increasing the number of users and critical for paying customers. The views of the service working groups were mapped into the four means of generating the impact.

5.3 Collaborative AEOLXI business model

As AEOLIX is a platform, it is not just a technology but a holistic business model that creates value by bringing together consumers and producers. Opposed to the dominant business models since the industrial era, AEOLIX will be governed by a platform business model (PBM). Rather than owning production and inventory like most traditional businesses, a PBM creates value by facilitating exchanges between two or more users, allowing users to both produce and consume information. The value proposition of AEOLIX is a combination of technology and the content that the users will create on top of it. AEOLIX value will lie both in its ability to host and stream user-defined content (e.g. data, services or both), and visualize it in a customized way via its dashboard. AEOLIX will set up the basis for an engagement after the project life to ensure the continuation of the collaboration of the stakeholders within the innovation platform.

AEOLIX - Benefits



The AEOLIX consortium is initiating the process of the “AEOLIX Not-for-profit legal entity” which would be responsible for the overall operation of a data and service centric platform for Europe-wide logistics services. This is in order to distinguish it from the current AEOLIX development and research activity. The makeup of this community would be similar in make-up to the Members of the AEOLIX Project, which comprises different types of supply chain stakeholders. The after project AEOLIX technical framework will consist of the technical platform and any functionality provided by the AEOLIX project (Dashboard, connectivity engine, SDK, etc.). Above all, the AEOLIX Legal Entity can play a key role in the market development process.

In closing, the AEOLIX platform alongside the CER-Log (Circular Economy Reverse Logistics) tool, can permit connected logistics operations to deliver visibility, reduce carbon, permit new business models to arise and support the European Commission directive to create better modality options across Europe.

6 Appendix

6.1 Design Documentation

An object-oriented language was decided on due to the extensibility of such an approach as well as the real-world application in question. By associating the current scenario to defined objects and behaviours, it is more intuitive to develop a real-world aligned simulation reflective of the current scenario. Furthermore, the flexibility afforded enables edge-cases to be prepared for, as well any initially out of scope considerations, such as non-standard transportation options, new Collection or Treatment plants, additional streams, variation in routing and/or multiple drop-offs.

Class Diagram

The first step of design was taking the real-world elements of the problem scenario and abstracting them into core classes. The key points of focus have been identified to be Collection Points (CP), Treatment Plants (TP), Journeys between the 2 (J) and the proposed Regional Centre (RC). These form a functional basis from which classes can be designed.

By first considering similarities between these points, 3 of 4 can be observed to be tied to a static geographic location, CP, TP and RC. Therefore, the first class will be “Point”, a class containing just Latitude and Longitude values detailing where it sits. As Journey acts as a discrete function with only overlap with other features in that it is conducted between them, there are no further abstractions to make on this. Finally, a consolidation centre acts as an intermediary between Collection and Treatment Plants (both of which are representable as points within a journey) with Journeys passing through them, and thus a final “Regional Centre” class is proposed. Leaving the final structure of classes to be:

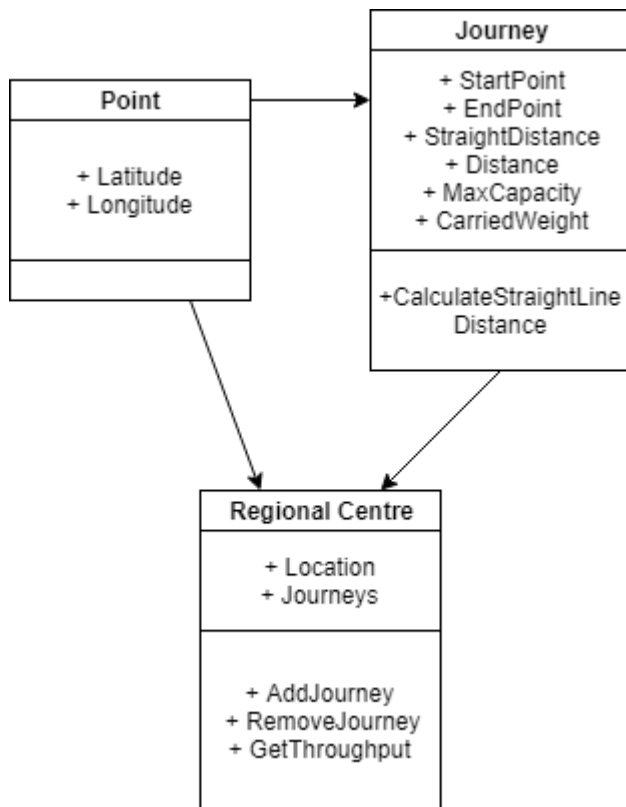


Fig.1 Journey Class

These chosen classes include therefore represent the entire baseline scenario, as well as the proposed addition of a consolidation centre. This encompasses entirely the problem and solution domains.

As shown in Fig.1 the Journey Class stores origin and destination points, an abstracted view of Collection Points and Treatment Plants. In addition to this, the straight-line distance between this is recorded in the case that a more accurate road-traced distance of the journey cannot be provided, and finally a carried and maximum capacity field should this data be available, this will be used in calculating potential consolidations.

Program Behaviour: Level 0 Design, System Overview

The overall program behaviour is made up of 5 primary steps, 4 of which, numbers 2 through 5, are automatic and entirely handled by the developed tool. The first, Geocoding data, required user intervention and must be performed as a prerequisite to successful usage of the tool. The Geocoding step must be manual due to the time and financial cost required to make this entirely automatic. This is made more complex where countries have no simplistic means through which to derive coordinates from addresses. To make this fully automatic, datasets of every possible input country would need to be sourced and stored locally within the program.

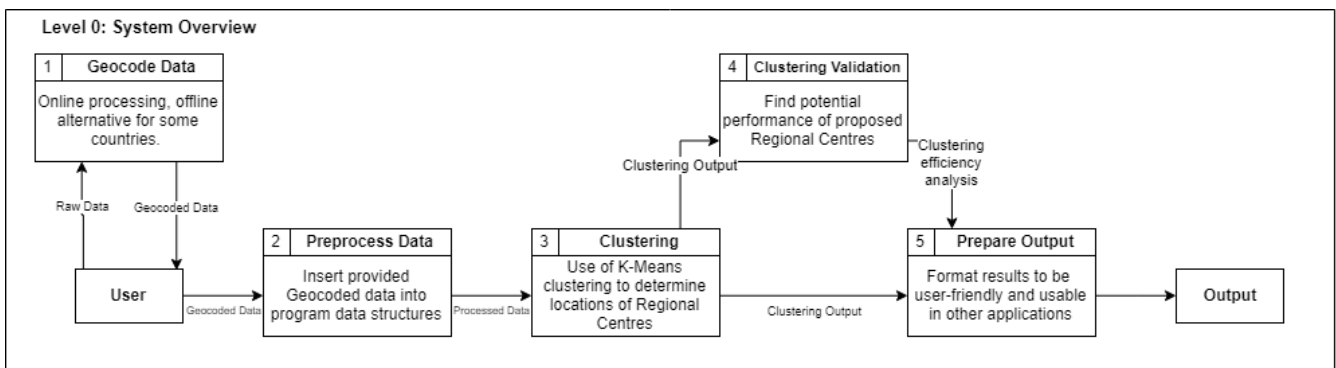


Fig.2 Program Behaviour: Level 0 Design, System Overview

Throughout this section each of these steps are considered in turn and broken down into its constituent steps, and the process chosen justified. Design considerations are explained and evidenced as to achieving the overarching aims of this task.

Program Behaviour: Level 1 Design, Geocoding Data

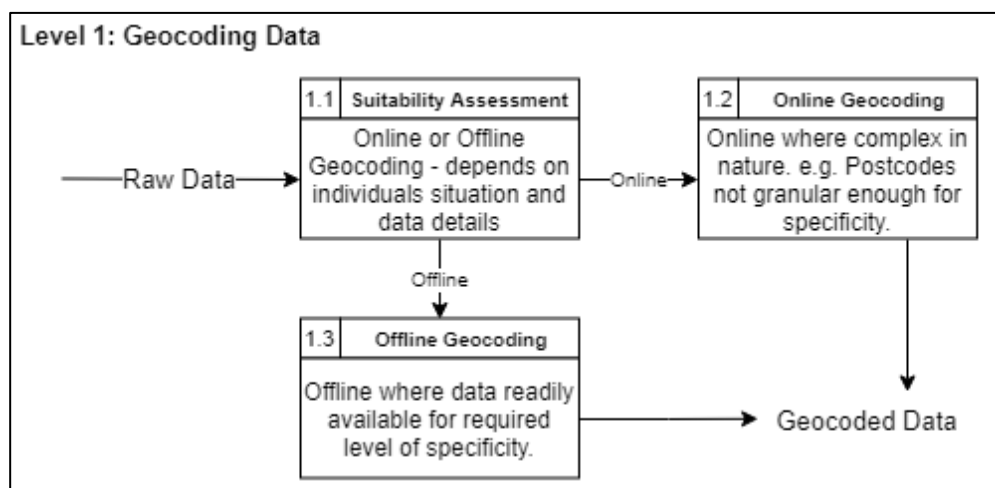


Fig.3 Program Behaviour: Level 1 Design, Geocoding Data

The user-requirement around successful usage of this tool is that data must be Geocoded. Whereas some geocoding datasets are both comprehensive and publicly available as is the case for England, others are often not comprehensive enough as to geographic accuracy of data, or are behind

paywalls. Therefore, to preserve uniform operation regardless of country of interest, the input data is assumed to have been geocoded beforehand. There are many methods through which that can be achieved, be it a self-developed script, VLOOKUP, or a paid service. Guidance will be provided as to completion of this step to not inhibit potential use.

The first step towards achieving geocoded data is determining whether the available datasets are suitable for offline geocoding, these are the manual, self-driven approaches. Where datasets are of suitable size such that Excel can process them, a VLOOKUP between postcodes and procured postcode to coordinate data can be executed for fairly trivial and quick geocoding. Alternatively, a programmed lookup-table can be utilised which can iteratively geocode a provided dataset to better handle larger ones. An example of this approach for England Geocoding has been developed and provided.

If an 'offline' approach is deemed unsuitable for any reason, then online alternatives do exist. For smaller datasets websites provide this function for free up to a daily quota, or alternatively there are several paid options. One of which is via the provision of a Google Maps API request key, which in turn charges your account for the number of uses, and another direct payment to the website for service provided.

Program Behaviour: Level 1 Design, Pre-processing Data

Level 1: Preprocess Data

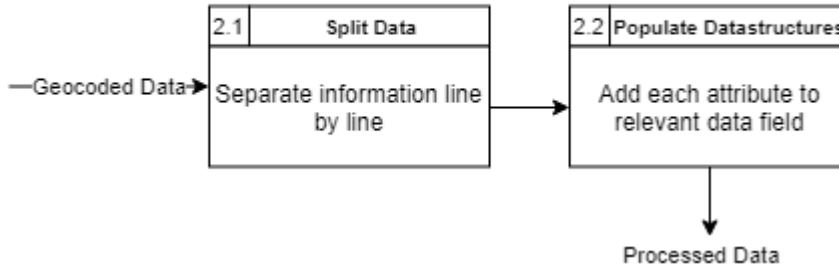


Fig.4 Program Behaviour: Level 1 Design, Pre-processing Data

Data pre-processing encapsulates the functionality of importing provided data into the data structures required for expected operation. As per the prior class diagram, each journey will be stored as a 'Journey' between two points, and each Collection Point/Treatment Plant stored as such too. Depending on the sizes of datasets it may be necessary to add safeguards into this process as to not be considering too large a data set as possible. In this case an amended design will be developed. In the case of larger data sets, similarly-located points will be considered in turn, and if further abstraction required, then each collection point will be handled individually during the pre-processing stage.

Program Behaviour: Level 1 Design, Clustering

Level 1: Clustering

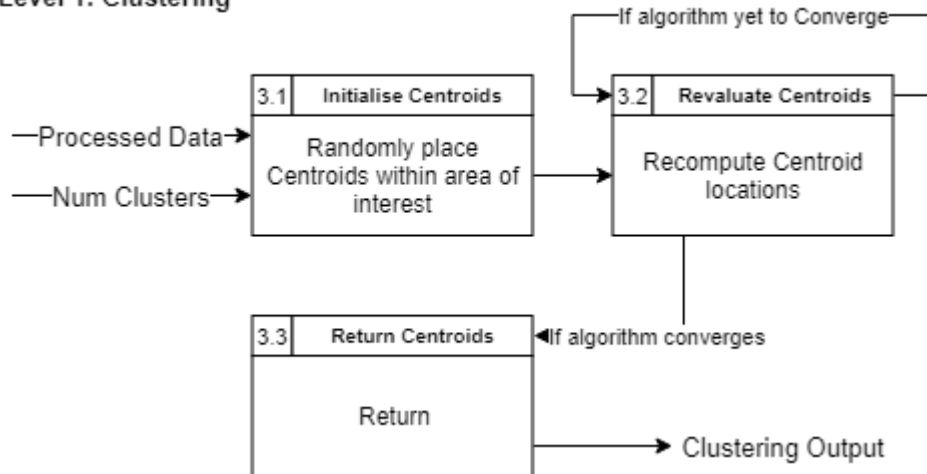


Fig.5 Program Behaviour: Level 1 Design, Clustering

One such requirement of this Algorithm is a user-specified number of clusters, which correlates in this instance to the number of Regional Centres. This is inferred via the 'Region' field of input data if present, otherwise a value of 1 is assumed. Albeit a potential barrier for use in that a particular user may not innately know the rough number of Regional Centres required within a region, it allows for determination of the most efficient number of Regional Centres via computation at various k-levels. The validation process further down the pipeline will assess the expected functionality of each k-scenario and provide the user an assessment of which is most efficient.

The k-means clustering approach is an iterative one and fairly trivial to implement. The first step of this algorithm is to initialise 'centroids' into random locations, which represent centre points of clusters, and thus the proposed location of Regional Consolidation Centres. These randomised locations are repeatedly recomputed based on the locations of surrounding points, Collection Points, until it converges, and the location remains fixed. At which point the algorithm returns the K clusters identified.

There are however extensions to the baseline algorithm which are due to be implemented, namely to consider throughput of each Collection Point. It will be the case that each Collection Point handles a different amount of recyclates, therefore, each Collection Point will have a different output to Treatment Plants. By assigning weightings to Collection Points relative to their throughput, the centroid will tend towards those with higher throughput and thus result in a more efficient location for potential Consolidation/Regional Centres.

Program Behaviour: Level 1 Design, Clustering Validation

Level 1: Clustering Validation

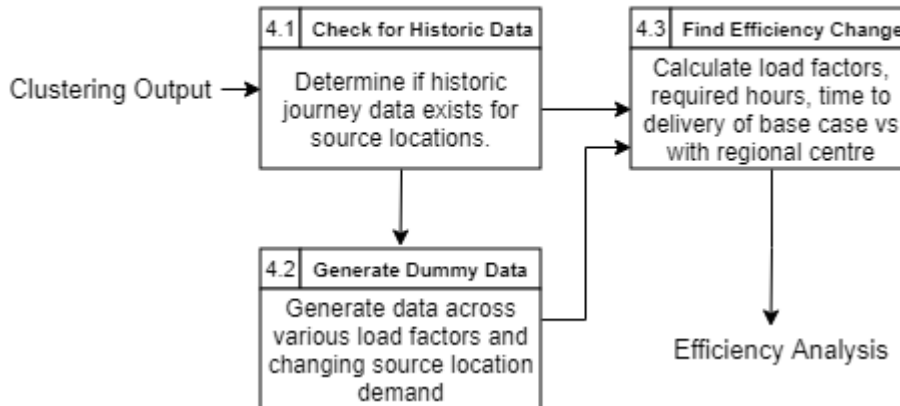


Fig.6 Program Behaviour: Level 1 Design, Clustering Validation

Every data set will be in one of two formats, either a list solely of Collection Points/Treatment Plants within the area of interest, or as a list of journeys made between these points. In the case of the latter, this provides a means for validation in a direct comparison between ‘before regional centre’ and ‘post regional centre’ scenarios.

Where the former is only available, dummy test data will have to be generated. In this case there further will be no means to generalise or assume throughput between collection points. Test data will be generated at incremental load factors will slight variation in collection point demand to better reflect a real-life scenario. This will result in a load factor at which the proposed Regional Centre will prove to be more efficient than the current process and indicate to the user at what point establishment of such a Regional centre will be beneficial.

There are several metrics used to ascertain efficiency of the Regional Centre, these being average load factors, and thus the expected fuel requirements, the required time to delivery as consolidation will take up more time, and actual on-road hours, further affecting both emissions and time. It will be at the discretion of the user whether the potential improvements justify the means.

Program Behaviour: Level 1 Design, Prepare Output

Level 1: Prepare Output

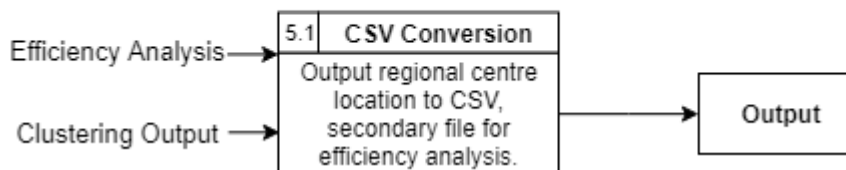


Fig.7 Program Behaviour: Level 1 Design, Prepare Output

To streamline and provide more meaningful analyses, the programs output will be provided to the user in CSV formatting for further usage in their preferred medium. This CSV is proposed to include the Regional Centre locations as well as the validation results.

6.2 Testing

Testing Methodology

Within this tool there are a multitude of input configuration cases to consider, each of these will be tested as an individual unit. Further integration testing must occur between some of the units, these being:

- 1) Taking User Input
- 2) Calculating locations for Regional and National Consolidation Centres
- 3) Simulating efficiencies considering the new Regional Consolidation Centres
- 4) Simulating efficiencies considering a National Consolidation Centre
- 5) Preparing the outputs from sections 2, 3 and 4

As there is an intuitive pipeline across these functionalities, integration testing will be an iterative approach starting with 1 and 2, and incrementally adding in 3, 4 and 5 in turn until the entire planned functionality is accounted for and tested.

Case	Testing Methodology	Test Description	Expected Result
1	Unit	Verifying the tool can take input from a user-defined location. Further, that erroneous file configuration/extension types are flagged.	Given a file path, the tool will recognise a file at said location. Should this files configuration not adhere to an expected functionality level, to flag this issue, similarly should the file type extension not be CSV to also flag this issue.
2	Unit	Finding Regional/National Centre locations for Functionality Level 1 – where input journey information is just Latitude/Longitude information of Collection Points/Treatment Plants.	As no Region information provided, should be identical results between Regional and National approaches. Furthermore, the proposed location should be the centre of gravity for the provided points.
3	Unit	Finding Regional/National	Different results between Regional and

		Centre locations for Functionality Level 1 – where input journey information is Latitude/Longitude information of Collection Points/Treatment plants as well as Regional/Stream information.	National solutions, where Regional results the centre of gravity for each region, and national for the entire set.
4	Unit	Finding Regional/National Centre locations for Functionality Level 2 – where input information is Latitude/Longitude information of Collection Points/Treatment Plants, as well as the handled/maximum capacity.	As no Region information provided, should be identical results between Regional and National approaches. Furthermore, the proposed location should be the centre of gravity for the provided points. Capacity information only concerned where calculating efficiencies.
5	Unit	Finding Regional/National Centre locations for Functionality Level 2 – where input information is Latitude/Longitude information of Collection Points/Treatment Plants, as well as the handled/maximum capacity. Further includes Regional/Stream information.	Different results between Regional and National solutions, where Regional results the centre of gravity for each region, and national for the entire set. Capacity information only concerned where calculating efficiencies.
6	Unit	Finding Regional/National Centre locations for Functionality Level 3 – where input information is Latitude/Longitude information of Collection Points/Treatment Plants, as well as the journey distance.	As no Region information provided, should be identical results between Regional and National approaches. Furthermore, the proposed location should be the centre of gravity for the provided points. Journey information

			only concerned where calculating efficiencies.
7	Unit	Finding Regional/National Centre locations for Functionality Level 3 – where input information is Latitude/Longitude information of Collection Points/Treatment Plants, as well as the journey distance. Further includes Regional/Stream information.	Different results between Regional and National solutions, where Regional results the centre of gravity for each region, and national for the entire set. Journey information only concerned where calculating efficiencies.
8	Unit	Finding Regional/National Centre locations for Functionality Level 4 – where input information is Latitude/Longitude information of Collection Points/Treatment Plants, carried and maximum capacities, as well as the journey distance.	As no Region information provided, should be identical results between Regional and National approaches. Furthermore, the proposed location should be the centre of gravity for the provided points. Capacity and Journey information only concerned where calculating efficiencies.
9	Unit	Finding Regional/National Centre locations for Functionality Level 4 – where input information is Latitude/Longitude information of Collection Points/Treatment Plants, carried and maximum capacities, as well as the journey distance. Further includes Regional/Stream information.	Different results between Regional and National solutions, where Regional results the centre of gravity for each region, and national for the entire set. Capacity and Journey information only concerned where calculating efficiencies.
10	Unit	Simulating each Region considering the newly proposed Regional Consolidation Centre to	A measure as to time saved/efficiency increase that is possible when using

		ascertain new efficiency	the proposed Regional Consolidation Centre.
11	Unit	Simulating each Region considering the newly proposed Regional Consolidation Centre to ascertain potential efficiency when using provided real-world data.	A measure as to time saved/efficiency increase that is possible when using the proposed Regional Consolidation Centre.
12	Unit	Simulating over all provided journeys considering the newly proposed National Consolidation Centre to ascertain new efficiency.	A measure as to time saved/efficiency increase that is possible when using the proposed National Consolidation Centre.
13	Unit	Simulating over all provided journeys considering the newly proposed National Consolidation Centre to ascertain new efficiency when using provided real-world data.	A measure as to time saved/efficiency increase that is possible when using the proposed National Consolidation Centre.
14	Unit	Ensuring the information generated by the tool (Regional and National Consolidation Centre locations & their respective efficiencies are formatted correctly in the output.	2 CSV files output, one containing location information for Regional/National Consolidation centres formatted such that it can be imported into a piece of GIS software. Second CSV containing brief description of the potential efficiencies of each approach.
15	Integration	Ensuring the data provided by the user is utilised and used by the calculation mechanism for determining centres of gravity.	Observe the correct data being passed to said mechanism.
16	Integration	Ensuring that once the centres of gravity are calculated, the simulation of Regional Consolidation Centres receives this information.	Observe the correct data being passed to said mechanism.
17	Integration	Ensuring that once the	Observe the correct

		centres of gravity are calculated, the simulation of National Consolidation Centres receives this information.	data being passed to said mechanism.
18	Integration	Ensuring the information formatted into the output documents corresponds to that calculated in prior steps.	Observe the correct data being passed to said mechanism.

6.3 Testing Results

Case	Outcome	Changes Necessary?
1	When provide a valid file-path in an accessible location, the tool functioned as expected. When provide a file-path in a non-accessible (permission restricted) location, an error is displayed. When provided a file-path in a non-existent location, and error is displayed.	No
2	Calculations were performed as expected. The regional and national outputs were identical.	No
3	Calculations were performed as expected. The regional and national outputs differed, with the number of regional centre outputs aligned to the number of regions input.	No
4	Calculations were performed as expected. The regional and national outputs were identical.	No
5	Calculations were performed as expected. The regional and national outputs differed, with the number of regional centre outputs aligned to the number of regions input.	No
6	Calculations were performed as expected. The regional and national outputs were identical.	No
7	Calculations were performed as expected. The regional and national outputs differed, with the number of regional centre outputs aligned to the number of regions input.	No
8	Calculations were performed as expected. The regional and national outputs were identical.	No
9	Calculations were performed as expected. The regional and national outputs differed, with the number of regional centre outputs aligned to the number of regions input.	No
10	When provided with real data, the efficiency of such a proposed configuration of Regional Centres is output, alongside a Boolean value (1 or 0) stating whether the	No

	new location would improve overall efficiency of that region.	
11	When provided with real data, the efficiency of such a proposed configuration of Regional Centres is output, alongside a Boolean value (1 or 0) stating whether the new location would improve overall efficiency of that region.	No
12	When provided with data, the efficiency of a proposed configuration including a National centre is output as well as a Boolean value stating whether the national consolidation centre makes an improvement.	No
13	When provided with data, the efficiency of a proposed configuration including a National centre is output as well as a Boolean value stating whether the national consolidation centre makes an improvement.	No
14	When outputting locations proposed for Regional and National consolidation centres, a CSV is returned including Region number (if relevant) as well as the centres respective Latitude/Longitude location.	No
15	Data is being passed between methods as expected.	No
16	Data is being passed between methods as expected.	No
17	Data is being passed between methods as expected.	No
18	Data is being passed between methods as expected.	No

As these Test Cases cover the entire range of proposed use cases, there are no alterations required. Should any further implementation take place, then further testing of such functionalities should be included to ensure expected operation has not altered.

6.4 User guide

Minimum Requirements

Tool usage is centred around command-line operation. Prerequisite requirements are:

- 1) Java Runtime Environment (JRE) 8.0+
- 2) A copy of "PolyCE _3.3_Tool.class" and its dependent classes available from

Alternately, with experience in editing and compiling Java code, a version of the source code is provided at

User Input Requirements

Execution of the tool requires 2 user-defined inputs.

- 1) The data of interest as a CSV, organised in an accepted format (as explained in 7.2.1).
- 2) A number, 1-4, of the desired functionality.

Accepted Data Format

Input data is expected to be a .CSV file describing the

The following table indicates optional/necessary fields within the provided data and the format it is expected in. An explanation of each field is provided below.

Field	Optional	Data Type
Region	Yes	Integer, 1 to N where N is the nth Region
Source Latitude	No	Floating Point Number
Source Longitude	No	Floating Point Number
Destination Latitude	No	Floating Point Number
Destination Longitude	No	Floating Point Number
Carried Capacity	Yes	Floating Point Number (kg)
Maximum Capacity	Yes	Floating Point Number (kg)
Distance Travelled	Yes	Floating Point Number (km)
Stream	Yes	The Stream of Recyclates carried on said journey

Where a field is optional, it may be removed from the system, however the overall ordering of these fields must be maintained to ensure correct operation. Additionally, no extra fields are permitted for inclusion.

Functionality Types

As stated, there are 4 levels of functionality within the tool which are dependent on the data available within your data set. This functionality has been extracted from the core program to extend readability of the code should alterations to core logic be desirable.

Functionality Level	Description
1	Source/Destination Latitudes and Longitudes
2	Source/Destination Latitudes/Longitudes and Handled/Max Capacity
3	Source/Destination Latitudes/Longitudes and Journey Distance
4	Source/Destination Latitudes/Longitudes, Handled/Max Capacity and Journey Distance

These operation levels indicate both the required fields and the order in which they **must** appear in the input file. The tool determines which operation mode is required based on the field and number thereof observed.

Example Accepted Formats

1.1.1.1 Level 1 Functionality Formatting

Collection Latitude	Collection Longitude	Treatment Latitude	Treatment Longitude
69.37	36.241	92.591	80.929
65.853	62.653	4.626	60.788
20.36	68.39	82.994	4.678
74.424	94.681	7.659	57.841
92.426	70.217	79.231	44.892
96.133	7.837	2.722	34.19
94.043	3.821	60.851	53.859
72.709	58.074	93.619	77.207
77.454	8.672	79.529	39.49
12.128	15.791	70.814	26.854

1.1.1.2 Level 2 Functionality Formatting

Collection Latitude	Collection Longitude	Treatment Latitude	Treatment Longitude	Carried Capacity	Maximum Capacity
69.37	36.241	92.591	80.929	273	300
65.853	62.653	4.626	60.788	114	300
20.36	68.39	82.994	4.678	148	300
74.424	94.681	7.659	57.841	262	300
92.426	70.217	79.231	44.892	272	300
96.133	7.837	2.722	34.19	277	300
94.043	3.821	60.851	53.859	256	300
72.709	58.074	93.619	77.207	174	300
77.454	8.672	79.529	39.49	245	300
12.128	15.791	70.814	26.854	130	300

1.1.1.3 Level 3 Functionality Formatting

Collection Latitude	Collection Longitude	Treatment Latitude	Treatment Longitude	Distance
69.37	36.241	92.591	80.929	59
65.853	62.653	4.626	60.788	144
20.36	68.39	82.994	4.678	93
74.424	94.681	7.659	57.841	125
92.426	70.217	79.231	44.892	104
96.133	7.837	2.722	34.19	132
94.043	3.821	60.851	53.859	74
72.709	58.074	93.619	77.207	145
77.454	8.672	79.529	39.49	191
12.128	15.791	70.814	26.854	80

1.1.1.4 Level 4 Functionality Formatting

Collection Latitude	Collection Longitude	Treatment Latitude	Treatment Longitude	Carried Capacity	Maximum Capacity	Distance
69.37	36.241	92.591	80.929	273	300	59
65.853	62.653	4.626	60.788	114	300	144
20.36	68.39	82.994	4.678	148	300	93
74.424	94.681	7.659	57.841	262	300	125
92.426	70.217	79.231	44.892	272	300	104
96.133	7.837	2.722	34.19	277	300	132
94.043	3.821	60.851	53.859	256	300	74
72.709	58.074	93.619	77.207	174	300	145
77.454	8.672	79.529	39.49	245	300	191
12.128	15.791	70.814	26.854	130	300	80

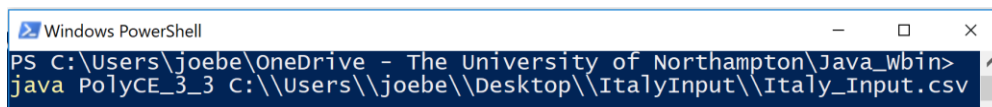
1.1.1.5 Added Regional Information

Region	Collection Latitude	Collection Longitude	Treatment Latitude	Treatment Longitude	Carried Capacity	Maximum Capacity	Distance
1	69.37	36.241	92.591	80.929	273	300	59
1	65.853	62.653	4.626	60.788	114	300	144
1	20.36	68.39	82.994	4.678	148	300	93
1	74.424	94.681	7.659	57.841	262	300	125
1	92.426	70.217	79.231	44.892	272	300	104
2	96.133	7.837	2.722	34.19	277	300	132
2	94.043	3.821	60.851	53.859	256	300	74
2	72.709	58.074	93.619	77.207	174	300	145
2	77.454	8.672	79.529	39.49	245	300	191
2	12.128	15.791	70.814	26.854	130	300	80

6.5 Example Tool Input Lines

1. Navigate to the directory containing the downloaded .class files.
2. Execute command “java PolyCE_3_3 *filepath_to_input*”

The output will be saved at the same location as the input file.



```
Windows PowerShell
PS C:\Users\joebe\OneDrive - The University of Northampton\Java_wbin>
java PolyCE_3_3 C:\\Users\\joebe\\Desktop\\ItalyInput\\Italy_Input.csv
```

Here the final line is the user-input component.

6.6 Video instruction for tool use

- Video instructions on tool use - <https://youtu.be/2PGDcndcRTU>
- Video instruction on GIS use - <https://youtu.be/PWBplq7Cqyg>

6.7 Tool Considerations

Throughout the development lifecycle of the final tool, a number of considerations had to be made in regard to functionality, scope and results. Encompassing the entirety of the Reverse Logistics domain for instance would have been wholly infeasible. Alternatively, by carving out a region of bespoke, reusable and extensible functionality, it has been possible to develop a useful standalone application which lends itself well to augment analyses over an area of interest when considering the potential of consolidation to remedy network inefficiencies.

Despite this smaller area of interest, there are numerous avenues of information afforded by this tool, regardless of the information available on a particular operation. By tailoring any solution to be functional at a baseline of Latitude/Longitude information, any operation is able to gain beneficial insight. The considerations discussed here will be justifications on why the available functionality is as it is, as well as why potential extensions were not included at the current time.

General operation of the tool is performed in the command line. This decision was made to enable a uniform operation modality which is abstracted from system dependencies on particular library UIs offered within Java. For example, a UI designed for usage on a Windows system will differ from that on Mac or Linux. An unfortunate side effect of this however is the

sacrificed usability, by saving time in designing bespoke user interfaces, the solution is less user-friendly than it could otherwise be.

Manual Mapping is a requirement with the output centres. Due to the chosen development language being Java and lack thereof experience using mapping alternatives to QGIS, a largely python-driven development, it was infeasible to devise an intermediary translation between the two applications given the time and available man-hours. The output identified locations of consolidation centres on both regional and national scales are however formatted such that there is easy addition to any GIS mapping system.

Offline Operation was similarly necessitated by development timeline and available man-hours. An online repository, albeit convenient, demands additional work in ensuring confidential data remains as such, acquiring the necessary resource to host an online as well as the configuration of such resource.

By making these considerations around restricting the final scope of the solution, it was possible to develop a more holistic approach to this scenario. Consequently, this has enabled the general-case solution to be made meaning as many analyses can be conducted as is deemed necessary.

Whereas these features would have been beneficial additions, they are not required as to the core functionality of the tool, or in the solution to task 3.3.

Extensions

The core extensions sit outside of functionality and in enhancing the ease-of-use for individuals without any prior technical knowledge and therefore usage of the current command line requirement. Therefore, the first extension would be to design and develop a user interface which works across all platforms. This would require significant development time dependent on the technology used, though due to provision of source code, if deemed vital for usage it is something organisations could develop in-house.

The next usability addition would be seamless integration into a GIS system, as it stands operation hinges on the user taking the output centroids file and inserting it to GIS software of their preference. A benefit to this approach being that users are able to use the software they're most comfortable with, however, this is still a manual step which requires additional knowledge to complete.

Finally, an Online repository of data, assuming such safeguards were integrated to it to prevent unintended access to sensitive data, would be a worthwhile addition for purpose of having a dedicated set of publicly (or privately) available open-source data. Further value can be derived from such a repository via storage of results and automated analyses for future use.

Shifts from Design

Throughout development a number of shifts from the initial design were made due to more optimal solutions being discovered, or due to time restrictions on the development cycle demanding less generalised, but just as functional, solutions.

The first alteration was made to the Class Design diagram, initially 4 were planned for, including a Treatment Plant class on top of those 3 detailed. This was deemed unnecessary considering there was no additional internal functionality to consider within a Treatment Plant, so instead they are abstracted to being just geographic Points.

The functionality for calculating straight-line distance originally sat within the Journey class, taking 2 Points as input. This was altered to sit within the Point class taking a single Point as input and a comparison of the parent point and input point was made instead.

Additional fields have been added to the Journey class to account for greater functionality or more streamlined calculations. A 'Stream' field was added to each journey to keep track of which streams were transported on a particular journey. This allowed for tracking of the current amount of each stream being stored within a Regional Centre and thus consolidations made around this value. The second addition was of a 'Region' field, which allowed a user to define Regions within their base data based on an integer value from 1 to N, where N is the number of regions considered.